

Setting Research Priorities: A Taxonomy of Policy Models

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Abstract- In recent years there has been a wide discussion in S&T policy fora on the intrinsic value of countries defining S&T priorities. This paper addresses the international situation with regard to these issues, by comparing a group of 27 different countries. An empirical exploration of data regarding S&T activities in those 27 countries is carried out, in order to infer through cluster analysis different ‘types’ or ‘models’ of S&T priority setting. The analysis shows that two major patterns of scientific publication exist, with some countries concentrating on “engineering and technology” publications while others concentrate on “health-related” themes. A second important aspect is that some countries tend to select R&D areas targeting “socio-economic objectives” to be financed by public funds while others give priority to a more blue-sky research. Larger countries, namely those that have stronger military interests, tend to be part of the first group. Finally, it is shown that providing less earmarked funds does not necessarily mean lower private participation in national R&D activities. By illuminating what are the existing models of research priority setting the paper intends to have a practical value for both policy-makers and analysts.

I. INTRODUCTION

In recent years there has been a wide discussion in S&T policy fora on: the intrinsic value of countries defining S&T priorities with regard to national development and innovation policies; whether those priorities should be made explicit by policy makers or only taken as implicit and formulated in general terms; the extension of those priorities, in terms of number of objectives and specifying detailed goals; the degree of involvement of different economic and social actors in the prioritizing of certain areas.

This paper addresses the international situation with regard to these issues, by comparing a group of 27 different countries.

In the sequence of this introduction the paper is divided into two main sections. Section II is dedicated to the discussion of what “priority setting in S&T” is. Section III is an empirical exploration of data regarding S&T activities from those 27 countries, in order to infer through cluster analysis different ‘types’ or ‘models’ of S&T priority setting.

By illuminating what are the existing models of priority setting in S&T the paper intends to have a practical value for both policy-makers and analysts. Further, this sort of systematic information might be particularly relevant for countries where the S&T system is undergoing rapid changes

or for the developing nations to whom the definition of S&T priorities is becoming a central aspect of their policy agenda.

II. PRIORITY SETTING IN S&T: WHAT ARE THE MAIN ISSUES?

A. Background

The publication of “Science the Endless Frontier” in July 1945 signalled the deep change occurred in the relationships between science, technology and society as a result of the war effort. In fact, modern science’s promise that through the knowledge of the laws of nature we could transform the world was finally being fulfilled through the development of science-based technologies. The main points of “Science the Endless Frontier” were that science was part of the US’s future, that it was necessary to organize the application of new scientific knowledge to technology and that the strengthening of the scientific basis was a legitimate concern of government.

But it took more than a decade (the launching of Sputnik by the USSR in 1957) to make the American public and society aware of the need to advance in new scientific fields leading to promising technologies. On May 25, 1961, J. F. Kennedy announced to the US congress his plan of landing a man on the Moon and returning him safely to Earth before 1970. As it is well known, the efforts associated with this objective had a strong impact on the S&T performance of the US economy in the coming years. Now, more than 4 decades latter, the US still keeps a strong flow of public resources to basic and applied R&D, namely in relation to the health, energy, defence and food sectors, through a complex system of federal agencies, public labs and research universities. It is widely recognized that these US arrangements have generated important spillovers harnessing the development of microelectronics, IT, biotech, the internet and other civilian and military technologies.

Many other countries have developed comparable systems of setting up S&T priorities. It is the recognition by economists of a market failure in R&D activities that has led to a generalised support of scientific activities and, in many cases, also of pre-competitive R&D. However, apart differences in the sheer volume of R&D financing, important variation exist in the institutional arrangements for priority setting up. In some cases the resources are distributed among disciplinary areas and then allocated exclusively or mainly in accordance to scientific merit and other academic criteria. In contrast, in other cases clear technological options are

identified and the scientific priorities ensue from those options. While the degree of public intervention on these matters varies significantly, in the more advanced countries it is common nowadays that the private sector also participates in the financing of science, thus affecting the priorities. Further, the participatory mechanisms vary widely, with different models of parliamentary intervention, demand for scientific advice or systematic inquiry of S&T stakeholders.

B. What "Priority-setting in S&T" is?

One might briefly define priority setting in S&T as a process of strategic nature that aims at: increasing the returns on public investments in research; increasing the relevance of research for socio-economic objectives (competitiveness, growth, welfare...); linking research with a society's long-term aims.

In practice priority setting in S&T involves two major aspects: decisions about allocation of resources; and coordination of different actions and actors that are involved in the S&T policy process. What is sought is a coherent integration of these two aspects, with the purpose of maximizing impacts while at the same time guaranteeing the overall efficiency of the process. As much of the R&D is carried out with public funds, governments need sound criteria to define how much public resources should be allocated to R&D and, in particular, to decide how to allocate those funds to different areas and objectives. It is in this context that the need for priority setting arises.

There are numerous examples of priorities in S&T set in the most developed economies over the last decades. It was mentioned in the previous section the cases of the nuclear bomb and space exploration in the US. During the World War II the attempt of developing a military jet aircraft, by the German Luftwaffe, is also well known. After the war many countries promoted nuclear programs, with civilian or military purposes or both. In the 1970s France set out a national project which outcome was the TGV (Train à Grand Vitesse). Germany developed a similar project a few years latter, promoting concurrently a technology similar to the French TGV (which outcome was the ICE trains) and the magnetic levitation technology (which was brought close to the commercialization stage by the Transrapid consortium). In the US in the 1970s the Nixon administration allocated massive resources to develop a cure for cancer, but the knowledge barriers showed insurmountable at the time to reach that objective.

All these well-known cases have to do with a "mission-oriented" style of S&T policy. However, following Ergas' [1] suggestion of distinguishing between "mission-oriented" and "diffusion-oriented" policy designs, one might also refer to S&T priorities clearly set in terms of diffusion-oriented policies, through the support of scientific-technological infrastructures, the dissemination of information and the provision of adoption incentives. The case of agricultural technologies in the US is probably a remarkable example. The establishment of the land-grant colleges and the promotion of very active agricultural extension services is part of a strategy that has been successfully promoted since the late XIX

century. Also in many countries the creation of research and technical entities aiming at the promotion of public health objectives, though campaigns of massive vaccination or the spreading of proper hygienic practices, shows how important S&T priorities have been set out in connection to diffusion-oriented policies, since many decades ago. More recently, the "information society" programs established in many countries might also be seen as an example of S&T priority setting in relation to diffusion-oriented policies.

All the previous examples, both in relation to "mission-oriented" and "diffusion-oriented" policy designs, relate to practical outcomes in areas such as defense, public health, energy, transportation or food production. They are mainly "technological" in their scope (rather than scientific) and they have to do with the satisfaction of societal or economic needs. However governments also set out research priorities related to intended scientific outcomes. These priorities have however, as it will be seen a more qualitative or functional nature, rather than a "mission" or "diffusion-oriented" nature.

Priority setting in S&T and in relation to research policy has gained a new momentum in recent years [2] [3]. The decision to establish a European Research Area, put forward by the European Council as part of the Lisbon agenda, has stimulated a debate about rationalization of investments and research priority setting in Europe. The EU policies in this area have been promoting 'thematic' priorities together with 'functional' (or 'structural') priorities, as a new model of organizing research across the EU space has been intended. In other parts of the world, namely in countries such as Japan or Korea, priority setting has remained high in the research agenda over the last few decades. The use of foresight tools in Japan as a means of developing "visions" and pin-pointing areas of future interest has been a long-standing characteristics of the Japanese innovation system. The organization of the RTD framework programs in Europe, in the sequence of ESPRIT, BRITE and other similar programs launched in the early 1980s, can in part be seen as inspired by the Japanese method of defining S&T priorities [4], which was seen as a successful example to be followed at the time.

However, despite S&T priority setting being widely implemented in many countries, through formal or informal mechanisms of participation and decision-making, its acceptance is not universal. The orthodox liberal view on this subject, recognizing the existence of market failure, is that governments shall exclusively fund basic science and define a proper regulatory framework, namely through intellectual property laws providing adequate protection to innovators [5]. This view in some circumstances combines with the wishes of scientific autonomy of the research community, which seeks to define internally the rules for allocating resources devoted to research. However, even in contexts dominated by liberal policies the orthodox view is subverted by a sense of 'real-politik' and complex machineries for defining priorities have been developed, with integration of public and private interests. The consequence of this pragmatic stance has been the emergence in the advanced countries of different versions of innovation policies that seek to explicitly integrate the

objectives traditionally addressed by S&T policies with economic growth and international competitiveness objectives [4].

C. The process of Priority Setting in S&T: how is it organized in practical terms?

This section addresses the practical problems faced by S&T priority setting. We assume here R&D funding as the main instrument of S&T policies, therefore identifying 'S&T priorities' as being 'research priorities'. In 5 successive steps we will discuss: (a) What are the priorities of public spending in research?; (b) How explicit they are?; (c) What mechanisms are used for setting these priorities?; (d) How is this decision-making process shaped?; and (e) Who are the participants of this process? This discussion aims at helping us in establishing a proper framework for our research about the models of priority setting in different countries.

What are the priorities of public investment in research?

As it was seen above important priorities have been defined in the past within the context of "mission-oriented" policies, aiming at the development of practical products or solutions. However, in many cases research priorities have assumed a more qualitative dimension, establishing as their key objectives reaching 'academic excellence' or the 'internationalization' of the national research community. An aspect that has been a central issue in many debates is the balance between basic versus applied R&D. In recent years many governments and private industry have sought to favor research with practical results or with outcomes visible in a given time horizon. This push towards 'results' has been criticized by many that advocate that a very significant share of research budgets shall be kept for blue-sky research without any specific immediate or specific practical targets. However, even when this longer-term stance is assumed, choices should be made between scientific disciplines and their respective sub-areas, or on whether to fund research on a disciplinary basis or in alternative stimulate more cross-disciplinary approaches.

How explicit are S&T priorities?

We assume that all governments that allocate public funds for research necessarily have a set of priorities attached to their decisions. The point is therefore not so much about the existence of S&T priorities *per se* but more about how explicit are those priorities. In some cases priorities are made explicit through formal mechanisms established for that purpose. In these cases the procedures of priority setting are recognized as an important component of the S&T policy process. In other cases, however, S&T priorities are the outcome of implicit processes, stemming from unspoken agreements and past decisions, and are embedded in the inertia of the R&D system. Of course, this distinction opens the door for discussing which of these two approaches might be more effective.

What mechanisms are used for priority setting?

Being S&T policy an activity developed at the government level, it implies that ministries and the public administration are involved in the definition of the priorities in this area.

However, this is a complex process. First of all S&T policies are simultaneously promoted by different ministries and government departments. In many countries a S&T ministry with a leading role in this area exists, but in other countries a more decentralized approach has been adopted, with the health, transportation, agriculture, industry or defense ministries playing decisive roles in the funding of R&D. This has been the case of the US, where this approach has stimulated diversity and as such deemed as a comparative advantage in relation to other countries. In any case intra-government coordination with regard to prioritization and allocation of funds seems to be necessary. In some cases this has been done by the finance ministry, in the annual budgeting rounds, but in some countries, such as Finland, national S&T councils chaired by the Prime Minister have been set up with this purpose.

An important distinction in relation to the machinery used for S&T priority setting, seems therefore to be the degree of centralization (versus decentralization) of this process. In one extreme, government ministers with the help of top civil servants might take the critical decisions. This would be a strictly 'top-down' approach. This process can be expanded through the involvement of parliaments, with the approval of the budget law or other national laws affecting S&T options. In reality, in most advanced economies there are now a large number of consultative and advisory bodies, such as higher S&T council or disciplinary research councils that take prominent roles in this process. Further, other participatory mechanisms have been set up, such as clustering schemes, foresight exercises or disciplinary or thematic conferences and initiatives with the purpose of involving different stakeholders. The involvement of 'users' is also becoming more frequent in some countries, favoring 'bottom-up' arrangements such as technology assessment exercises or ethical councils that may have a voice in relation to certain research programs.

How is the decision-making process shaped?

The process of defining S&T priorities is implemented in a given institutional setting that depends on historical trajectories, national cultures and a multiplicity of contextual factors. One of those contextual factors is whether a 'national vision' about the future exists.

In this context, an important aspect is whether 'research' is part of such a national strategy. The strength of that vision in what concerns S&T might have to do with the capacity of different groups formulating well their own views. To assess that vision one would need therefore to answer to questions such as: Do business firms know what they want out of the research carried out in the country?; Do they have the capacity to influence the national research agenda?; Do the military have similar capacity?; Does civil society (NGOs...) has mechanisms to affect the research agenda?

Who are the stakeholders?

We have just hinted above about who are the intervening parts in this process: governments; civil service structures; national or regional parliaments; business interests; the

military; NGOs... Another key group participating in this process is of course the scientific community. In smaller countries it may speak as a unified voice, but typically different influential voices might be heard, emanating from big research institutes, different disciplines or influential individuals. Increasingly, the media have been playing an important role. Also, international organizations in some aspects have been influencing the shaping of national policies, through bench-marking exercises and diffusion of 'best-practices' (this is the OECD case), or through effective mechanisms of coordination and policy homogeneity (such as in the EU case).

III. ANALYSIS OF DIFFERENT NATIONAL PRIORITIES IN S&T

What will be presented now is an empirical exploration of data regarding S&T activities from 27 different countries, in order to infer through cluster analysis different 'types' or 'models' of S&T priority setting. These results are part of an ongoing project, through which we aim at putting forward a taxonomy of S&T priority setting approaches.

At the present stage the analysis is based on secondary data provided by the OECD and the US NSF [6]. The fact these data are not available for the developing countries means that we concentrate on the OECD economies plus Russia. However, even within the OECD there are countries with quite different characteristics in terms of economic development, size, GDP growth rates, etc. We think this exploratory work is important in order to identify aspects and questions that will underpin the next research stage, which will involve the collection of primary data through questionnaires aimed at several developed economies plus the BRICS group of countries.

The analysis that will be carried out next develops along three successive steps: Analysis of Scientific Publications; Analysis of Scientific Publications plus the 'Socio-Economic objectives' of Public Spending in R&D; same as previous step, but adding to the analysis data about the weight of government financed R&D on total GERD.

The information that will be observed refers mainly to outcomes of the decision-making process or to certain performance characteristics of the research system. Given these data limitations, we will try to infer *ex-post* about the nature of existing S&T priority setting approaches in the 27 countries sample.

The collected data were submitted to cluster analysis (Ward method) and the statistical output was examined to provide a coherent explanation of existing patterns.

A. Initial Analysis

The NSF data collected on [6] refers to internationally refereed scientific publications by researchers from the 27 selected countries. The publications data were divided into two groups: "Health" and "Engineering and Technology" scientific publications. The first group comprises papers in Medicine and Public Health, together with papers in disciplinary areas which have stronger connections to 'Health' issues (this includes the 'Biomedical Sciences', 'Other Health

Sciences' and Biology). Following a similar logic, the second group adds together 'Engineering & Technology Papers' with Physics, Chemistry, and Mathematics.

TABLE 1
PROPORTION OF "HEALTH" AND "ENGINEERING AND TECHNOLOGY" SCIENTIFIC PUBLICATIONS

Countries	Health	Eng. & Tec.	Cluster
Russian Federation	15	80	2
Korea	34	63	2
Slovak Republic	36	54	2
Portugal	40	55	2
Czech Republic	41	54	2
Japan	47	51	2
México	47	48	2
France	47	46	2
Greece	50	44	2
Spain	50	44	2
Germany	51	44	2
Italy	52	43	2
Switzerland	54	41	2
Belgium	55	39	2
Australia	56	35	1
United Kingdom	55	34	1
United States	57	33	1
Ireland	59	33	1
Austria	61	33	1
Canada	60	32	1
Netherlands	61	32	1
Finland	62	32	1
Sweden	62	32	1
Iceland	63	32	1
New Zealand	60	30	1
Norway	62	29	1
Denmark	67	28	1

The dendrogram displayed in fig. 1 shows that the countries cluster clearly into two very distinct groups: one (which comprises most of the higher income countries) where 'health' papers dominate (55% to 67% of all scientific publications); and another one where 'engineering and technology papers' have relatively greater weight (and, as expectable, 'health' papers have lower shares of the total, ranging from only 15% in Russia to 55% of all scientific publications). These results indicate that in richer countries (cluster 1) 'health' related issues might be a more important priority than 'engineering and technology', while in countries closer to intermediary levels per capita of income (cluster 2) 'engineering and technology' seem to rank higher on the priority agenda. Of course these results should be understood on an average interpretation, since countries like Germany or France are also part of cluster 2.

Dendrogram using Ward Method
Rescaled Distance Cluster Combine



3 big clusters
8 smaller clusters

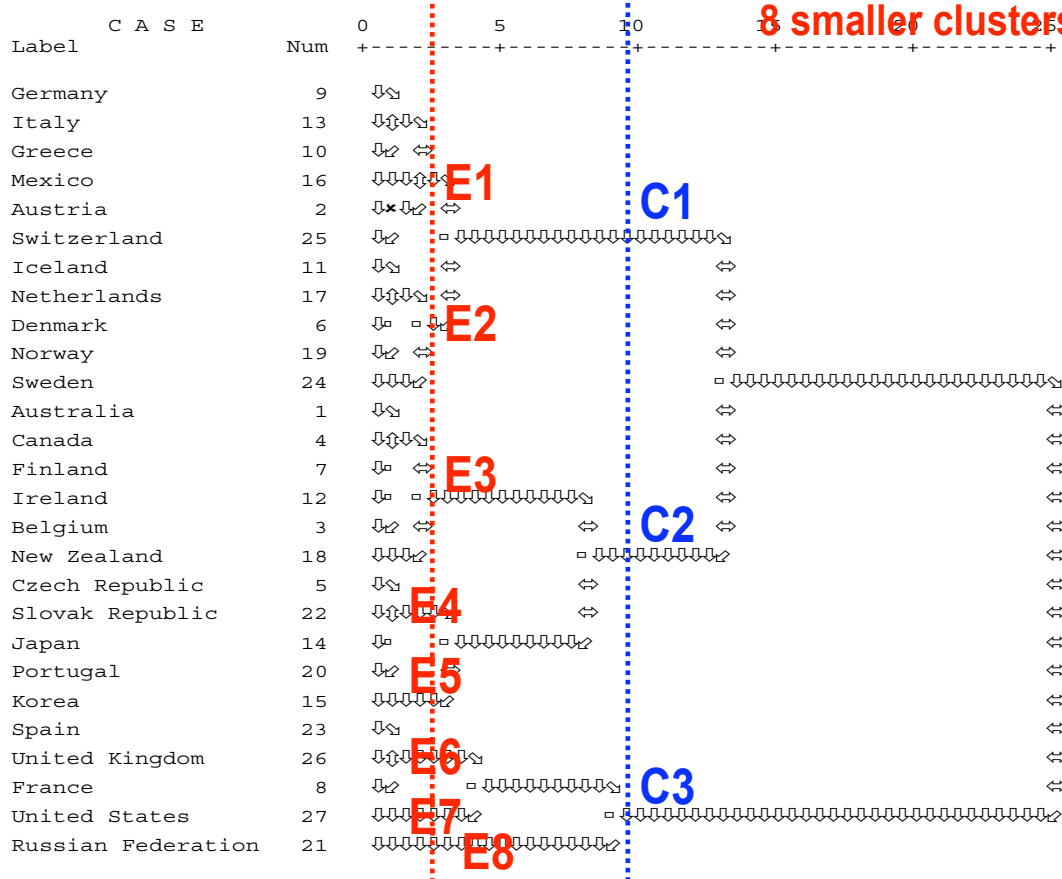


Fig. 2. Cluster Analysis of Scientific Publications plus the ‘Socio-Economic objectives’ of Public Spending in R&D

To facilitate the observation of the results of this second step of cluster analysis, we draw a two-dimensional chart (fig. 3). On the vertical axis of this chart we took the variables which were analysed in step 1 of the cluster analysis. Specifically, it was taken the ratio of “Health” versus “Engineering and Technology” publica-tions which assumes a value equal to 1 when the share of both types of publications is the same. In the center of the chart we draw a horizontal (pink) line indicating this ratio mean value for the 27 countries in the sample. On the horizontal axis, we took the weight of Non-Oriented Funds plus General University Funds (NOF+GUF) on total public spending on R&D. The vertical (pink) line indicates the mean value for this NOF+GUF variable for the 27 countries in the sample.

In addition to the NOF+GUF variable, other ‘socio-economic objectives’ might have been taken in building this chart, but our assessment is that NOF+GUF is the variable that most differentiates the 27 countries in terms of the ‘socio-economic objectives’ of public spending on R&D. Further, information about military spending is also explicitly taken into consideration in this chart analysis, with the figures written in red indicating the proportion of military spending on total public spending on R&D.

The observation of fig. 3 indicates that in any of the 3 larger

clusters there are countries with higher and lower ratios of “Health” versus “Engineering and Technology” scientific publications, but on average C2 as a higher value for this ratio and C3 a lower value. However, what really differentiates these 3 clusters is the weight of NOF+GUF on total public spending on R&D, with C2 ranking first (NOF+GUF \approx 60%), C1 second (NOF+GUF \approx 40%) and C3 third (NOF+GUF $<$ 30%). Further, it is clear that C3 has a much higher average military R&D spending (45%) than the other two largers clusters (which concentrate only 6-7% of total public spending on R&D in the military objective).

It is a very high public spending on military R&D that drew the E6 cluster (France, UK and Spain) into C2, together with the US (E7) and Russia (E8). It is interesting to note that Russia and the US have some important dissimilarities but at the same time they share some significant similarities. The case of Korea (E5) is also interesting, since this country ought to be a member of C2, rather than C1, if it had a higher proportion of its public spending on R&D concentrated on military purposes.

C2, which concentrates on the upper right quadrant of fig. 3, integrates the smaller E1 and E2 clusters. This position on the upper right quadrant indicates that these countries give a stronger priority to ‘blue-sky’ research, given a much higher

proportion of NOF+GUF spending. Most of the European nordic countries cluster on E2, being an exception Finland that seems to earmark more clearly its public spending on R&D to more explicit socio-economic objectives. Finally, it shall be

noted that the US together with Russia and Korea are in the opposite situation, with a smaller proportion of NOF+GUF spending. These 3 countries seem therefore to favor more explicit objectives.

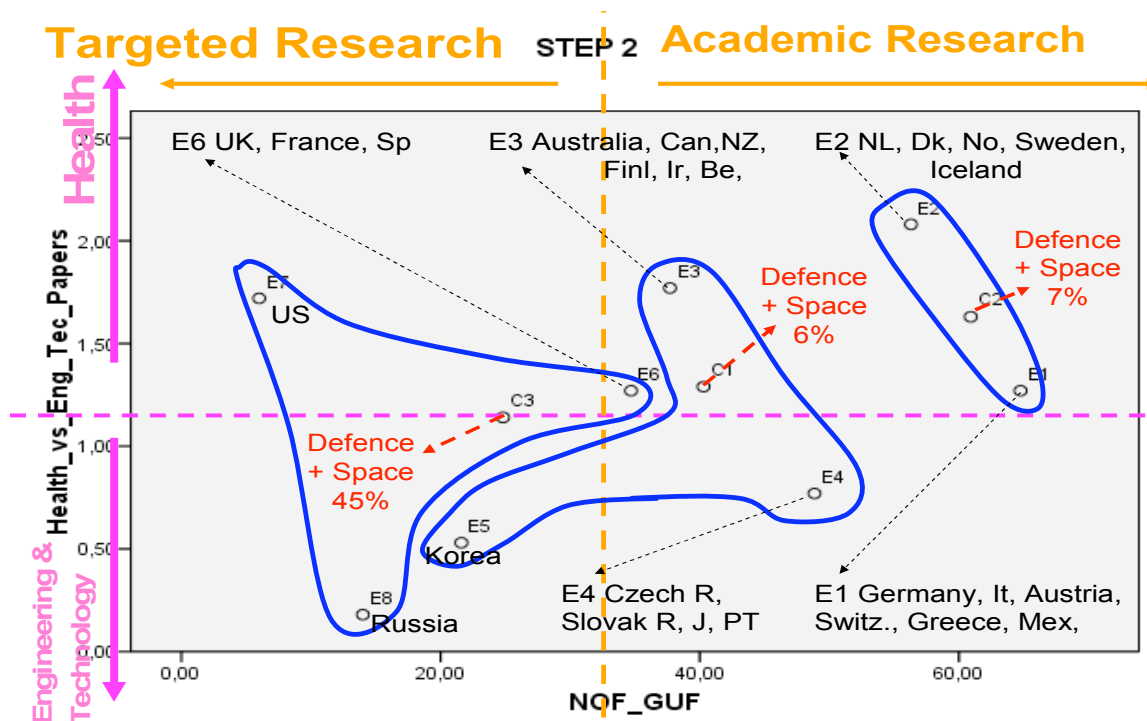


Fig. 3. Visualization of the clusters resulting from the Analysis of Scientific Publications plus the 'Socio-Economic objectives' of Public Spending in R&D

C. Integrated Analysis

The third and last step of the cluster analysis integrates a third dimension, beyond the orientation of scientific publication and the socio-economic objectives analyzed in the previous step. That third dimension has to do with the weight of government financed R&D on GERD (Gross expenditure on R&D). This ratio GFRD/GERD has a dual meaning, since it expresses the involvement of governments in R&D but it also indicates how business interests participate in the national research effort. Probably a high share of the business sector on total GERD (and a low GFRD/GERD ratio) indicates that private interests have a good capacity both to participate in the setting up of national R&D priorities and to influence the research agenda towards innovation objectives. On the contrary, a higher ratio of government financed R&D on GERD might be seen as indicating that academic or military objectives rank higher on the national research agenda.

Fig. 4 displays the results of the cluster analysis, that was carried out on the same 6 variables as before plus a new one, expressing the weight of government financed R&D on GERD. That chart shows 5 main clusters. To facilitate observation of these 5 clusters, we drew a two-dimensional chart (fig. 5) along similar lines to the one put forward in the previous section. We have again in the vertical axis the ratio of "Health" versus "Engineering and Technology" scientific publications and on the horizontal axis the weight of Non-Oriented Funds plus General University Funds (NOF+GUF) on total public spending on R&D. The novelty lies in the fact that we add to this chart the third dimension taken in step 3, given by GFRD/GERD. Specifically, we take in the chart the value of $(1 - \text{GFRD}/\text{GERD})$ by drawing blue and red arrows. 'Blue' indicates that $(1 - \text{GFRD}/\text{GERD})$ is below 55% of total GERD, while 'red' indicates that $(1 - \text{GFRD}/\text{GERD})$ is above 55%.

H I E R A R C H I C A L C L U S T E R A N A L Y S I S * * * * *

Dendrogram using Ward Method
Rescaled Distance Cluster Combine

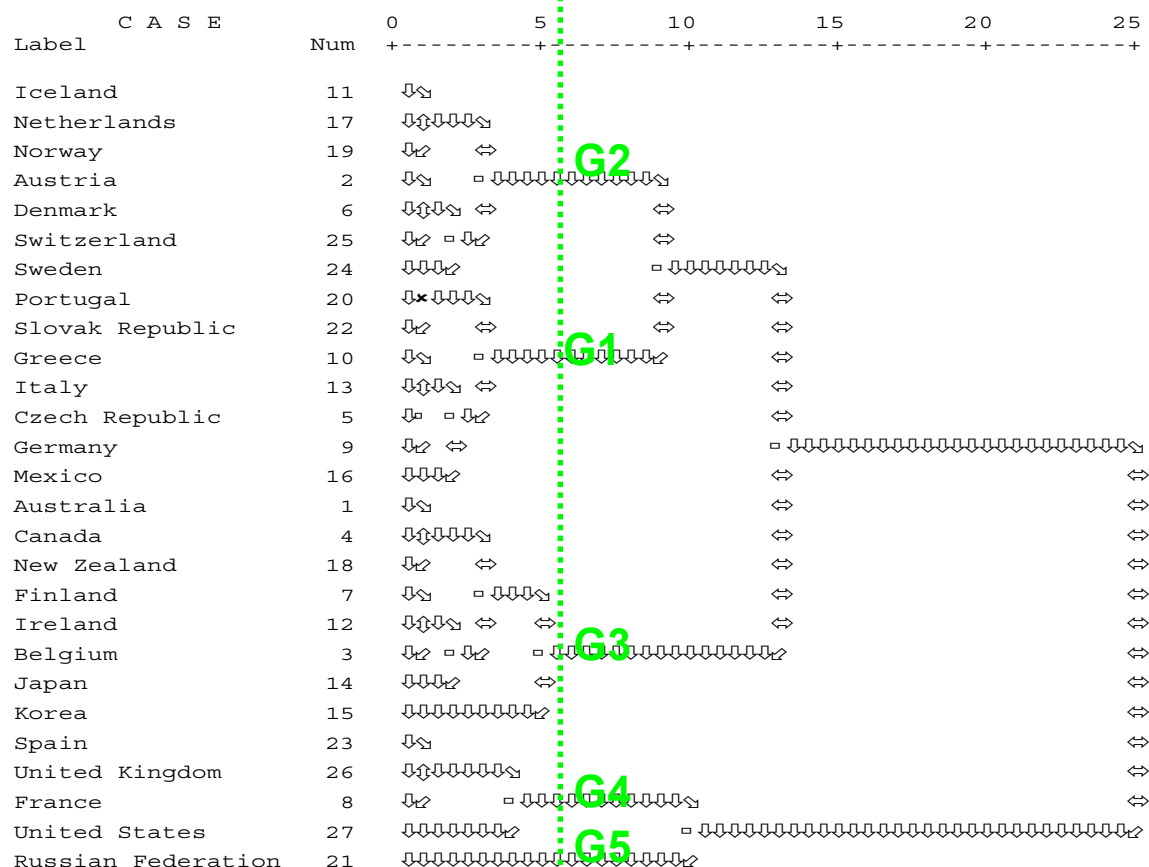


Fig. 4. Cluster analysis of Scientific Publications, the ‘Socio-Economic objectives’ of Public Spending in R&D and the weight of Government Financed R&D on total GERD

The three clusters on the top 3 quadrants of fig. 5 (G2, G3 and G4) have red arrows, indicating a strong participation of the private sector in financing R&D in those countries. The countries that cluster in G1 and G5 (Russia) have all lower levels of private participation in financing R&D, being here Germany, which belongs to G1, an exception to that general pattern. That is confirmed by looking at fig. 6, in which (1 - GFRD/GERD) appears on the vertical axis. What brings together countries in cluster G1 is probably the fact that all of them share a low intensity of specific socio-economic objectives, with a NOF+GUF proportion on total public spending close to 60% on average, together with a greater orientation towards “engineering and technology” publications.

On the two quadrants above clusters G2 and G4 are in contrasting positions with regard to the indicator expressing the weight of NOF+GUF on total public spending in R&D, while G3 is located somewhere between those two other clusters. Countries in G4 (US, UK, France, Spain) share a higher level of earmarked public spending in R&D, namely an important military orientation. In contrast, countries in G2 (smaller European economies) seem to favor ‘blue-sky’ research despite in all of them private business playing an important role in financing R&D. The intermediate cluster G3 (Japan, Korea, Canada, Australia, New Zealand, Finland and Ireland) have countries with an important orientation for specific socio-economic objectives but without investing a high proportion on military R&D.

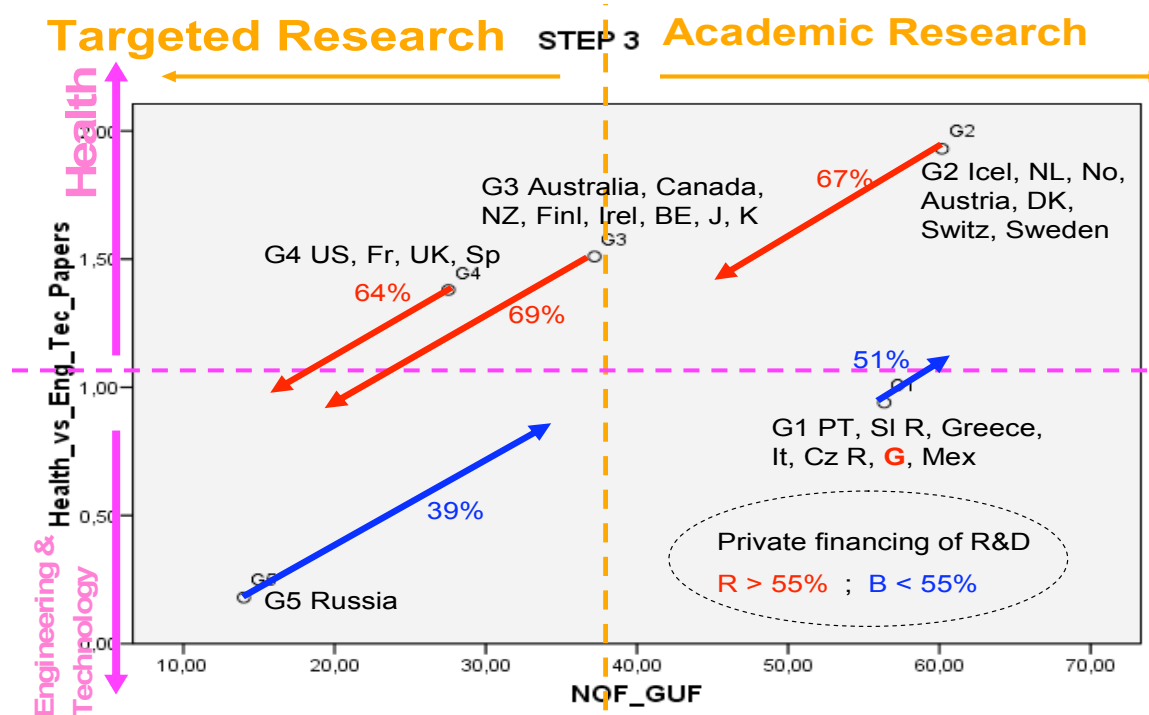


Fig. 5. Visualization of the clusters resulting from the analysis of Scientific Publications, the 'Socio-Economic objectives' of Public Spending in R&D and the weight of Government Financed R&D on total GERD

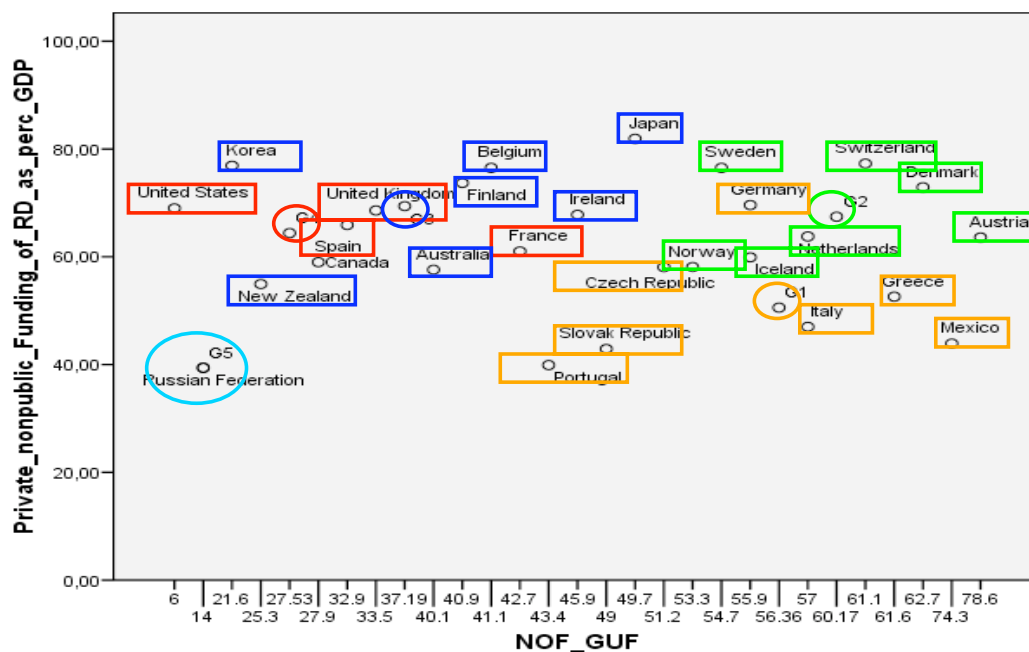


Fig. 6. Same as fig. 5 but taking (1-GFRD/GERD) on the vertical axis

IV. CONCLUDING REMARKS

This paper tackled the problem of which S&T priorities different countries have addressed. The analysis focused on the OECD universe plus Russia, given the shortcomings in international data sources about S&T activities.

Despite the limitations in the existing international databases and the fact that we have relied on secondary sources referring to *ex-post* aspects of the decision-making process, some pertinent aspects were highlighted by the analyses that were carried out. It is clear that two major patterns of scientific publication exist, with some countries

concentrating on “engineering and technology” publications and others on “health-related” themes. This second group is composed of higher income economies, where both major pharmaceutical companies have their headquarters and ageing populations supported by generous pension schemes create a demand-pull effect. A second important aspect that is revealed by our analysis is that some countries tend to select specific R&D areas (“socio-economic objectives”) to be financed by public funds while others give priority to a more ‘blue-sky’ research. Larger countries, namely those that have stronger military interests, tend to be part of the first group. Finally, it is clear that providing less earmarked funds does not necessarily mean that private participation in R&D is low.

Further research to be developed along similar lines should try to expand the sample, namely attempting to cover the BRICS universe. It should also bring in other variables that provide information about how decision-making in S&T leads to the definition of different sets of priorities. That might be possible through direct questionnaires sent out to expert panels.

The next stage of research will have to explore deeper the styles of priority setting in S&T, attempting to identify different “modes” or “types” of decision making. The analysis of “mission-oriented” versus “diffusion-oriented” priorities might be an important aspect to be analyzed, together with the consideration of “thematic” and “structural/functional” priorities connected to the functioning of the innovation system and the regulatory framework.

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